Management of soil erosion for sustainable crop production in the Central Andes of Colombia

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1. Abstract

Results of the research and extension project "Soil building and conservation for sustainable production of Andean Raspberry (*Rubus glaucus*) in steeplands of Colombian Andes are presented. Soil and water conservation technologies based on Zero tillage, contour planting, interplanting crops, and site specific selection of "noble weeds" as protective cover showed negligible soil losses in comparison with bare soil plots and conventional hoe tillage and weed management with herbicides.

2. Introduction

Erosion research in tropical steeplands has been historically ignored by scientific community, in part due to preconceptions created by the Land Use Capability Classification System that considers soils with slope greater than 20% unsuitable for cultivation because high susceptibility to erosion (Thurow and Smith 1998). In addition, concerns about soil erosion affecting soil productivity in smallholder agriculture in steeplands have resulted in an emphasis on trying to stop negative effects on crop yields attributed to erosion and runoff by putting cross-slope barriers in fields designed to catch or divert soil and water moving downslope (Shaxson and Barber, 2003). However, among resource-poor small farmers of tropical steeplands this approach has not been either particularly popular, or widely adopted or effective in stopping erosion processes or in raising yields (Obando 1999; Shaxson and Barber, 2003). They have proved to be uncomfortable with small farmers' livelihood systems, their capacities, resources or perceptions of productivity problems. Farmers' prior concerns are not related to soil erosion but rather to land shortages, increase crop production, market opportunities and family food security (Hellin, 2006). Thus, low yields of subsistence crops may dictate that they be planted on all land units irrespective of erosion hazard (Shaxson and Barber, 2003). Within this context, the research and extension project "Soil building and conservation for sustainable production of Andean Raspberry (*Rubus glaucus*) in steeplands of Colombian Andes was carried out with financial support of the National Program of Agricultural Technology Transfer, PRONATTA, of Ministry of Agriculture and Rural Development of Colombia (MADR). Main objectives were to get a better understanding of erosion process of Andisols in steeplands of Central Colombian Andes, and to test the effectiveness of both residue-based zero tillage cropping systems, interplanting crops and integrated management of noble weeds to control water erosion.

3. Methods

A conventional monocropping and hoe tillage system, three residue-based zero tillage and interplanted cropping systems and a reference bare soil treatment were tested as showed in Table 1. Experimental site, field methods and research layout are described thorough elsewhere (Obando et al., 2004). This research work was aimed at analyzing further the effects of contact cover, including residues and noble weeds, and canopy cover on erosion control. Thus, previous data were reanalyzed on the light of the concept of weighted cover factor, C_w, suggested by Morgan (1990) and calculated as the equation $Cw = \sum_{i=1}^{n} (C * fr)_i$ where C is the monthly crop factor as defined in the USLE equation (Wichsmeir and Smith, 1978) and fr is the ratio of the monthly cumulative erosivity index, EI_m, and the annual erosivity index, R, calculated as $fr = \frac{EI_m}{R}$.

4.Results

Annual soil losses were 16,054; 0,475; 0,701; 0,552 and 144,561 $Mg.ha^{-1}.y^{-1}$ for T1, T2, T3, T4 and T5 respectively (Table 2). There were significant differences between different treatments ($P<0.0001$) with a R^2 of

97%. T1 presented significant differences with T2, T3 and T4. There were significant differences between the reference bare soil plot T5 and T1. Even though, the integrated protective effect of contact and canopy cover of T1 (58.95%) as indicated in table 4, as well as contour planting lines of the raspberry crop contributed further to control 88,89% of the erosion risk relative to the reference bare soil plot.

Table 1 Soil and water conservation techniques and slope range

Treatment	Management practice	Slope range (%)
T1	Raspberry mono-cropping and conventional hoe tillage. Weed management with herbicides	37 – 49
T2	Raspberry inter-planted with maize (*Zea mais*) and beans (*Phaseolus vulgaris*), permanent cover, direct drill (zero tillage), selected covers of "noble weeds", management of crop residues	35 – 67
T3	Raspberry with zapallo (*Cucurbita maxima*, a variety of calabash;), permanent cover, direct drill (zero tillage), selected covers of "noble weeds", management of crop residues	41 – 44
T4	Raspberry inter-planted with maize (*Zea mais*), permanent cover, direct drill (zero tillage), selected covers of "noble weeds", management of crop residues	37 – 64
T5	Reference plot: Bare soil and cultivated along slope	48 – 52

Table 2 Monthly soil losses (Mg. ha^{-1}) for the experimental period

Month/year	T1	T2	T3	T4	T5
11/02	1,179	0,099	0,039	0,140	0,462
12/02	0,000	0,000	0,000	0,000	0,581
01/03	0,133	0,055	0,055	0,040	17,616
02/3	0,944	0,010	0,019	0,028	10,363
03/03	2,540	0,019	0,016	0,010	57,725
04/03	5,138	0,187	0,418	0,267	6,290
05/03	0,259	0,019	0,018	0,018	5,748
06/03	0,066	0,005	0,004	0,000	2,613
07/03	0,043	0,006	0,007	0,002	0,304
08/03	0,092	0,046	0,020	0,025	0,724
09/03	0,254	0,000	0,007	0,004	4,960
10/03	5,405	0,030	0,100	0,019	37,176
Total	16,054B*	0,475C	0,701C	0,552C	144,561A

* Means with the same letter are not significant different at the 95% confidence using Duncan´s Multiple Range Test. CV= 6%

Annual erosivity index (R) was 2047 MJ.mm.ha^{-1}.h^{-1}.y^{-1}. The erodibility index, K, calculated as the ratio of annual soil losses and R resulted to be 0.070 Mg. ha. h. ha^{-1}. MJ^{-1}. mm^{-1} (Table 3). For the same experimental soil, Carmona et al. (2004) found a R value of 3553 MJ.mm.ha^{-1}.h^{-1}.y^{-1}, soil losses of 125.35 Mg.ha^{-1}.y^{-1} and consequently a K value of 0.039 Mg. ha. h. ha^{-1}. MJ^{-1}. mm^{-1}. This K value is considered higher than those reported by Rivera and Rodriguez et al., quoted by Carmona et al.(2004) for Andisols of Colombian coffee zone with 70% slope and Canary Islands with 24% slope respectively. Evans cited by Morgan (1990) points out that soils with a restricted clay fraction, between 9 and 30 percent, are most susceptible to erosion, and Shoji et al., cited by Carmona et al.(2004) postulate that resistance to water erosion of Andisols depends to a great extent on resistance of aggregate to dispersion. Thus, the high erodibility factor is likely to be markedly influenced by the high sand content (64 %) as well as the relative low value of weighted diameter of water stable aggregates of 2.9 mm. Also, the R value is considered low in comparison with regional data. In fact, Dvorakova (2002) reports R values ranging between 2046 MJ.mm.ha^{-1}.h^{-1}.y^{-1} and 21959 MJ.mm.ha^{-1}.h^{-1}.y^{-1}. During the experimental period 193 storms occurred with a total rainfall of 1139 mm; however only 38 showers (20%) resulted to be erosive which explains in some way the low R value and consequently the high K value. There were significant differences in the weighted cover factor, C_w (P<0.0001) with a R^2 of 99.95 (Table 3). Figure 1 shows the functional relationship between *Cw* and the contact and canopy cover fraction (C_f) relative to that from the reference bare plot. The relationship is exponential following the equation $Cw = \exp(-a * Cf)$. The coefficient *a* has a value of 3.23, indicating a relative rapid exponential decline of *Cw* as contact and canopy fraction (C_f) increases. At C_f of about 0,70, this means, 70% of contact and canopy cover, the weighted cover factor, *Cw*, became 0,10 apparently indicating that 70% of contact and canopy cover may well be sufficient to control soil erosion to a level of 10%. This means, to control 90% of soil erosion at least 70% of contact cover is considered necessary. To control soil erosion to a negligible level a cover greater than 90% may be needed. Only T1, which has a C_f value of less than 70% has a *Cw* value greater than 0,10. The large reductions of soil loss observed in the residue-based zero tillage treatments, T2, T3 and T4, treatments were undoubtedly due to the great amount of contact cover as shown in table 4. In fact, values of contact cover calculated as the summation of residues and noble weeds were 80.24%, 76.08% and 84,57% for T2, T3 and T4 respectively.

Table 3 Monthly rainfall, erosivity, erodibility and weighted cover factor

Month/year	**Rainfall (mm)**	**EI**†	**K**‡	**weighted cover factor (C_w)**				
				T1	**T2**	**T3**	**T4**	**T5**
11/02	53	59	0,007831	0,073351	0,006194	0,002465	0,008727	0,028823
12/02	4	0	-	0,000000	0,000000	0,000000	0,000000	0,000000
01/03	9	23	0,765913	0,000125	0,000070	0,000046	0,000049	0,011236
02/3	83	225	0,046058	0,015992	0,000091	0,000259	0,000465	0,109917
03/03	175	654	0,088265	0,014025	0,000120	0,000093	0,000064	0,319492
04/03	120	124	0,050726	0,046976	0,001812	0,003967	0,002762	0,060576
05/03	87	108	0,053222	0,002964	0,000215	0,000188	0,000192	0,052760
06/03	83	86	0,030384	0,001911	0,000055	0,000239	0,000002	0,042013
07/03	27	17	0,017882	0,001479	0,000277	0,000146	0,000048	0,008305
08/03	69	83	0,008723	0,005204	0,002670	0,001154	0,001409	0,040547
09/03	96	239	0,020753	0,012343	0,000004	0,000113	0,000308	0,116756
10/03	335	429	0,086657	0,024785	0,000193	0,000600	0,000120	0,209575
Total	1139	2047	0,070621	0,199154B*	0,011701C	0,009271C	0,014147C	1,000000A

†($Mj.mm.ha^{-1}.h^{-1}.a^{-1}$); ‡ ($Mg.ha.h.ha^{-1}.MJ^{-1}.mm^{-1}$); means with the same letter are not significant different at 95% confidence using Duncan´s Multiple Range Test. CV= 4.6%.

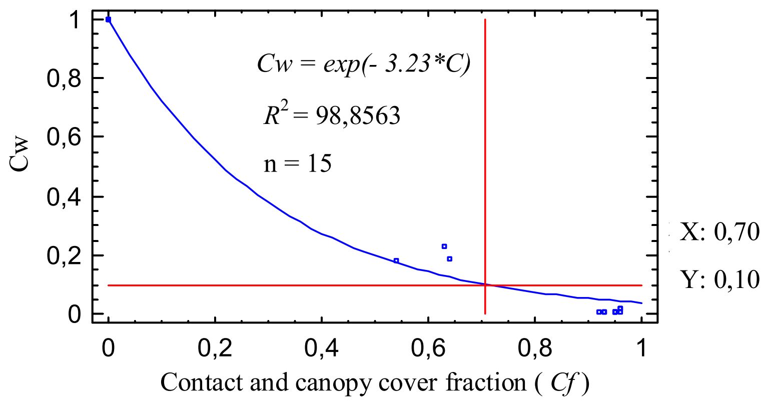

Figure 1. Weighted cover factor as affected by contact and canopy cover.

These results agree with those found in steeplands of Honduras, where to control 90% of erosion a soil cover of 75% was needed (Shaxson, 1999). From these results, it is concluded that in spite of erodibility index of the experimental soil is considered to a certain extent high, soil erosion in Andean steeplands might not be as severe as have been reported and erosion risk depends more on management practices of soil surface conditions than on slope *per se*. Consequently, the development of Land Capability Classification Systems as well as methods for monitoring and assessing soil erosion according with biophysical and social realities of tropical steeplands are highly recommended. The integrated approach of residue-based zero tillage, site specific management of noble weeds, contour lines and interplanted crops may lead farmers to achieve efficient erosion control and therefore more sustainable farming systems.

Table 4 Percentage of surface contact cover and canopy cover

Type	T1	T2	T3	T4
Residues of coniferous (*Pinus patula*), native shrubs and crops	27.71	44.70	39.89	50.27
Noble weeds	19.12	32.54	36.19	34.30
Interplanted crop	0.00	12.38	8.80	6.37
Raspberry crop	12.12	6.10	8.88	4.59
Total	58.95B	95.71A	93.75A	95.52A

* Means with the same letter are not significant different at the 95% confidence using Duncan´s Multiple Range Test. R2 = 93.5%; CV= 6.4%

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